Non-nuclear Methods for HMA and Soil Density

Yong K. Cho, Ph.D.
Associate Professor

Durham School of Architectural Engineering and Construction

April 4, 2012

UNIVERSITY OF NEBRASKA–LINCOLN

Outlines

I. HMA Testing

- A. Objective
- B. Data Analysis
- C. Error Modeling
- D. Conclusion and Recommendations

II. Soil Testing

- A. Objective
- B. Literature on Gauges
- C. Data Analysis
- D. Conclusion and Recommendations

III. Economic Analysis

I. HMA Testing

Objective

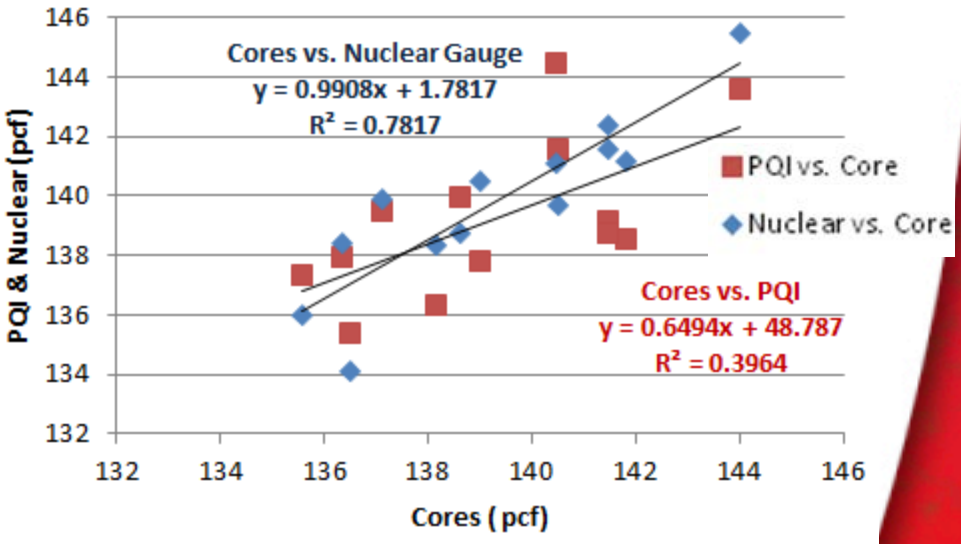
- Main research Objective is to study effectiveness of non-nuclear gauge (PQI 301) with the nuclear gauge (Troxler) and develop methods to improve non-nuclear gauge's performance for QC and QA
  - 13 sites were investigated for two years
  - Data size: 150 cores + more for calibration
  - SP4 and SPR used for the top layer of pavements




Gauges test results

- Two gauges densities were compared to corresponding core densities
- Average density error with cores:
  - PQI: 1.89 lb/cu.ft
  - Nuclear: 1.07 lb/cu.ft
- Site average (r^2)
  - PQI: (r =0.63, r^2=0.4)
  - Nuclear:

    (r=0.88, $r^2 = 0.78$)



Data Reliability (Core sample vs. MTD)

Core samples compared to the MTD(%)

Distribution of when exactly it is appropriate to reasonably accept gauge readings.

Core sample density compare to the MTD(%)	Num of Sample	% of the core	Difference with cores	
			PQI	Nuclear
86%	4	3%	5.79	5.01
87%	8	6%	4.68	2.96
88%	11	8%	3.48	3.33
89%	11	8%	1.96	2.49
90%	16	12%	0.71	0.77
91%	26	19%	0.78	0.96
92%	21	15%	0.70	0.36
93%	24	17%	1.14	0.63
94%	14	10%	2.02	0.20
95%	4	3%	4.89	0.14

Discovered th 9%) and
ninety three p n gauges
can be assur normally
distributed be

This is important information when cores are selected to calibrate PQI at first place

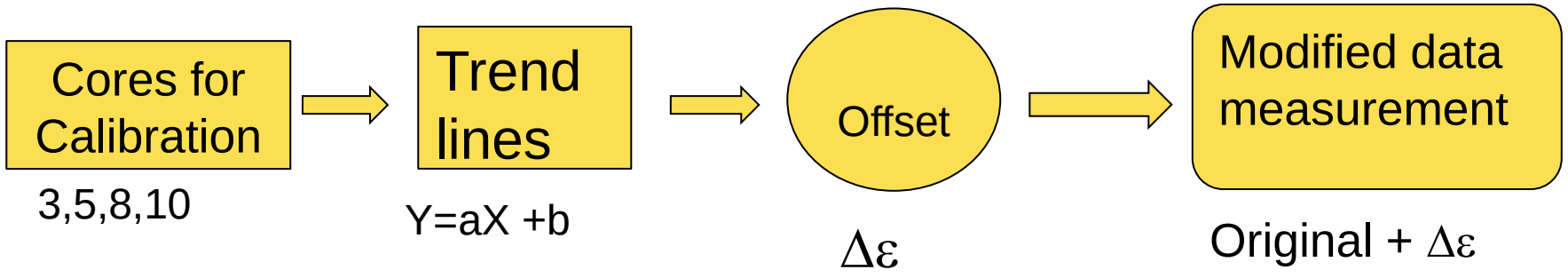
Data Reliability (Both Gauges vs MTD)

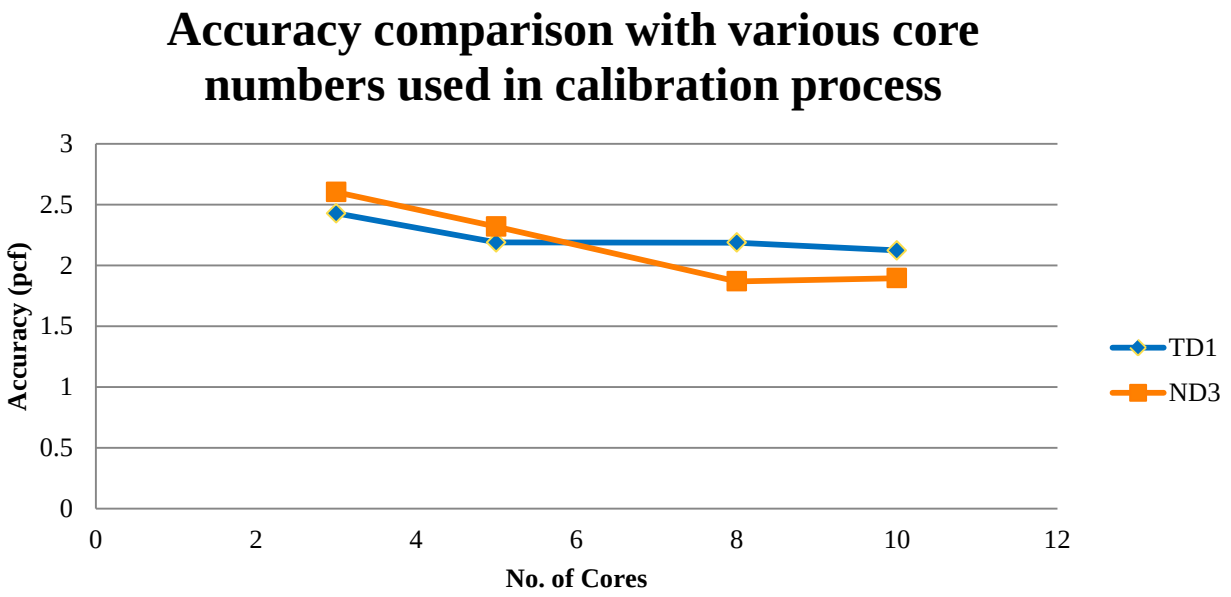
PQI and Nuclear densities compare to the MTD(%)

PQI and Nuclear gauge density compare to the MTD %	Num of Sample	Difference |PQI-Core|	Num of sample	Difference |Nuke –Core|
86~87%	1	6.32	3	2.56
87~88%	2	8.79	7	4.36
88%~89%	12	0.65	8	0.09
89% ~90%	15	1.52	13	0.19
90~91	45	0.41	27	1.13
91~92%	27	0.67	19	0.41
92~93%	18	0.58	27	1.7
93%~94%	10	0.68	17	0.75
94%~100	9	0.02	18	1.79

78.4%

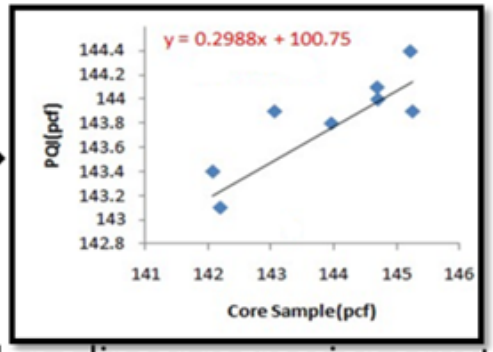
Error Modeling to Improve PQI Accuracy using core samples in calibration process





Summary of PQI improvement process

Calibrate PQI with 8 Cores ranging 89%-93% of MTD



Develop a linear regression equation with 8 cores

$y = ax + b$

Adjust PQI field data

Original + Δoffset

PQI readings ≥90 % of MTD

Use for QC and QA

PQI readings <90 % of MTD

Use traditional methods (e.g., core or nuclear gauge) to verify the PQI readings

II. Soil Testing

Objective

- Research objective is to investigate effectiveness of (Troxler's Nuclear gauge, Humboldt's EDG, Durham Geo's M+DI and Zorn's LWD) vs. Traditional Methods

- Research team follows:
  - Nuclear Method (ASTM D2922, AASHTO T-310) for Field & Lab tests
  - Known soil curves provided by NDOR
  - The Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method (ASTM D2937-10) – Shelby Tube
  - Standard Proctor Compaction Test
  - Water Content Determination by dry-oven method.

Electrical Density Gauge (EDG)

- Provides density, % compaction, moisture content.
- Needs a soil model to “calibrate” device
- Requires use of mold

Light Weight Deflectometer (LWD)

- Measures Stiffness of the soil
- Used by Mn/DOT for QA

Two Sites

- Highway 370 by Gretna, NE
- Platteview Intersection Site near Plattsmouth, NE
- Total of 118 spots were measured

Test results

	Density		Moisture	
	Nuclear vs. Standard	EDG vs. Standard	Nuclear vs. Standard	EDG vs. Standard
Coefficient of Correlation (R)	0.695	0.492	0.90	0.63
Coefficient of Determination (R squared)	0.483	0.24	0.76	0.40

LWD Test Analysis

- Issue in comparison: deflection vs. density
- A test is deemed passed or failed when the measured density is within 95% of the maximum density along with moisture requirements.
- Pass or Fail for LWD using Target value methodology adopted by Mn/DOT

1.48	P
2.43	F
1.42	P
2.37	F
1.75	P
1.57	P
1.37	P
1.45	P
2.18	F
1.36	P
2.56	F
2.08	F

Standard	Gauge
F	F
F	P
F	F
P	P
P	P
F	P
F	P
F	F
P	P
P	F
P	F
P	P

Test Status Analysis

Test Status Relationship with Standard Method	Site 1	Site 2	Average
Nuclear Gauge	83.30%	65%	77%
LWD	48.71%	67.50%	55.08%
EDG	41%	37.50%	39.80%

II. Economics Analysis

Economic Analysis

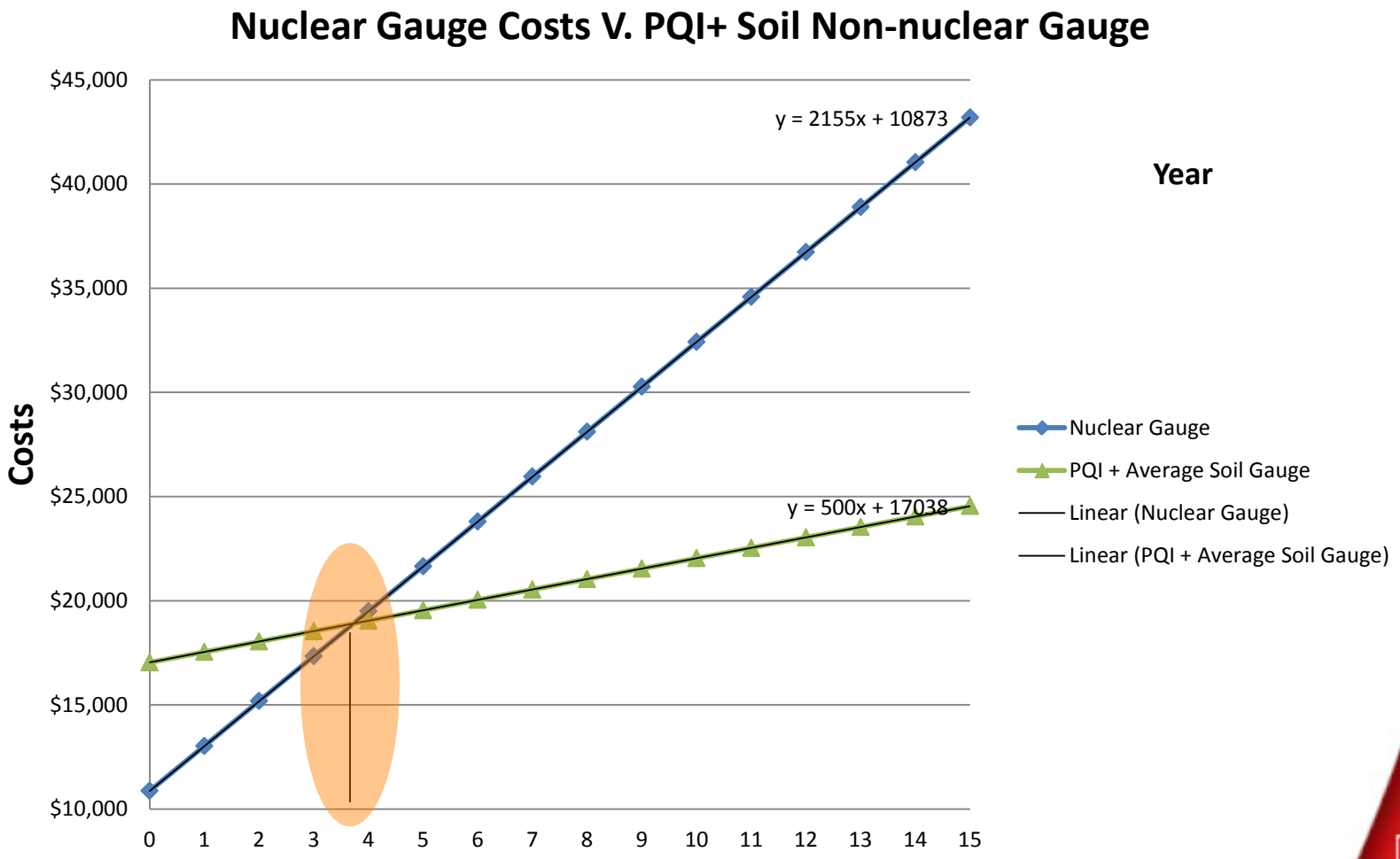
Nuclear Gauge Costs

Cost of nuclear gauge	$6,950
Radiation safety & Certification Class	$750
Safety training	$179
HAZMAT certification	$99
RSO training	$395
TLD Badge monitoring	$140/yr
Life of source capsule integrity	15 yr
Maintenance & Re-calibration	$500/year
Leak test	$15
Shipping	$120
Radioactive Materials License	$1,600
Re-licensing	$1500/ year
Reciprocity	$750

Economic Analysis

	Initial Costs	Annual Maintenance
EDG	$9,000	$0
LWD	$8,675	$0
PQI	$8,200	$500

Economic Analysis(Break Even Point)



3.73 years

New non-nuclear technologies

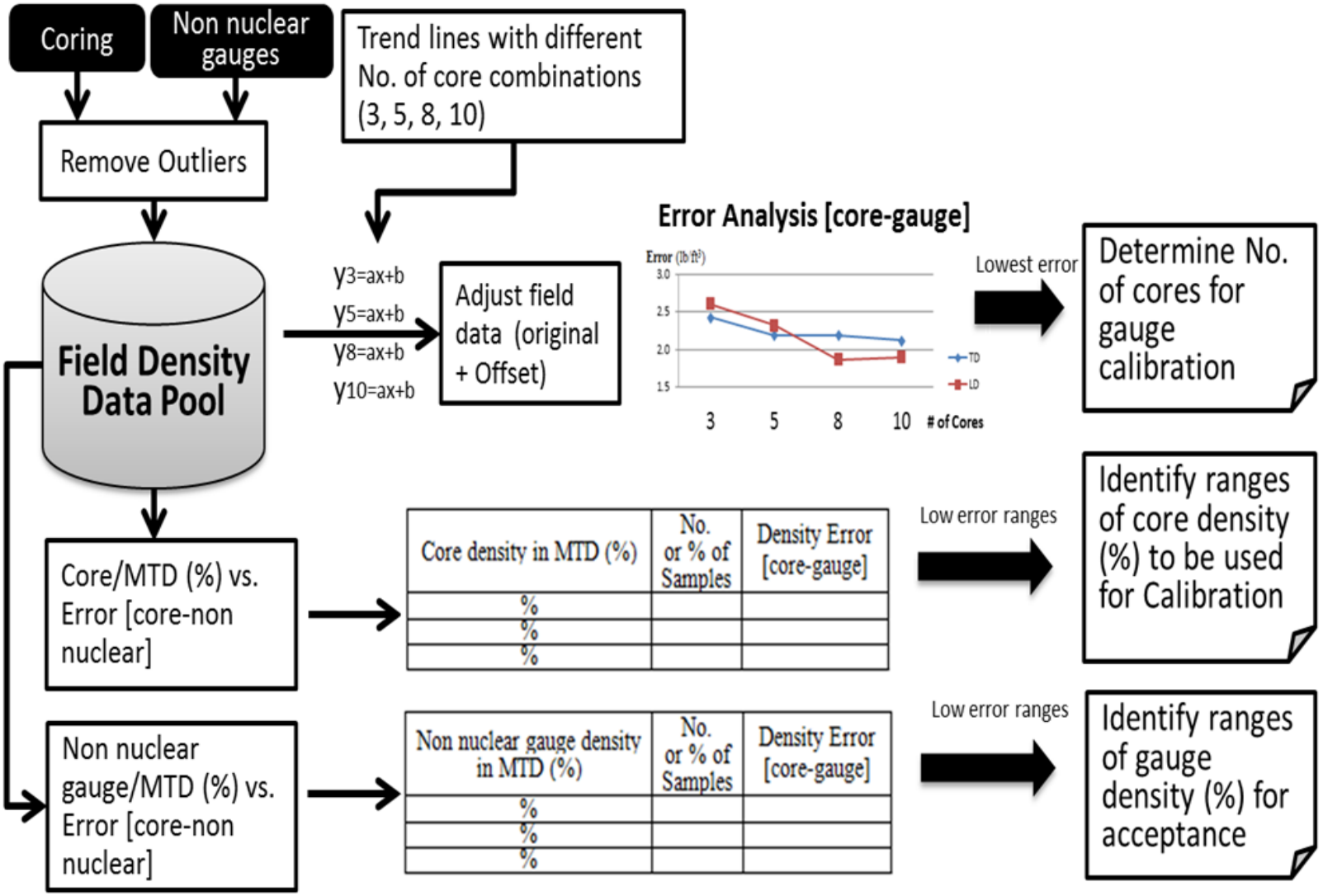
LWD for Asphalt

Troxler PaveTracker Plus

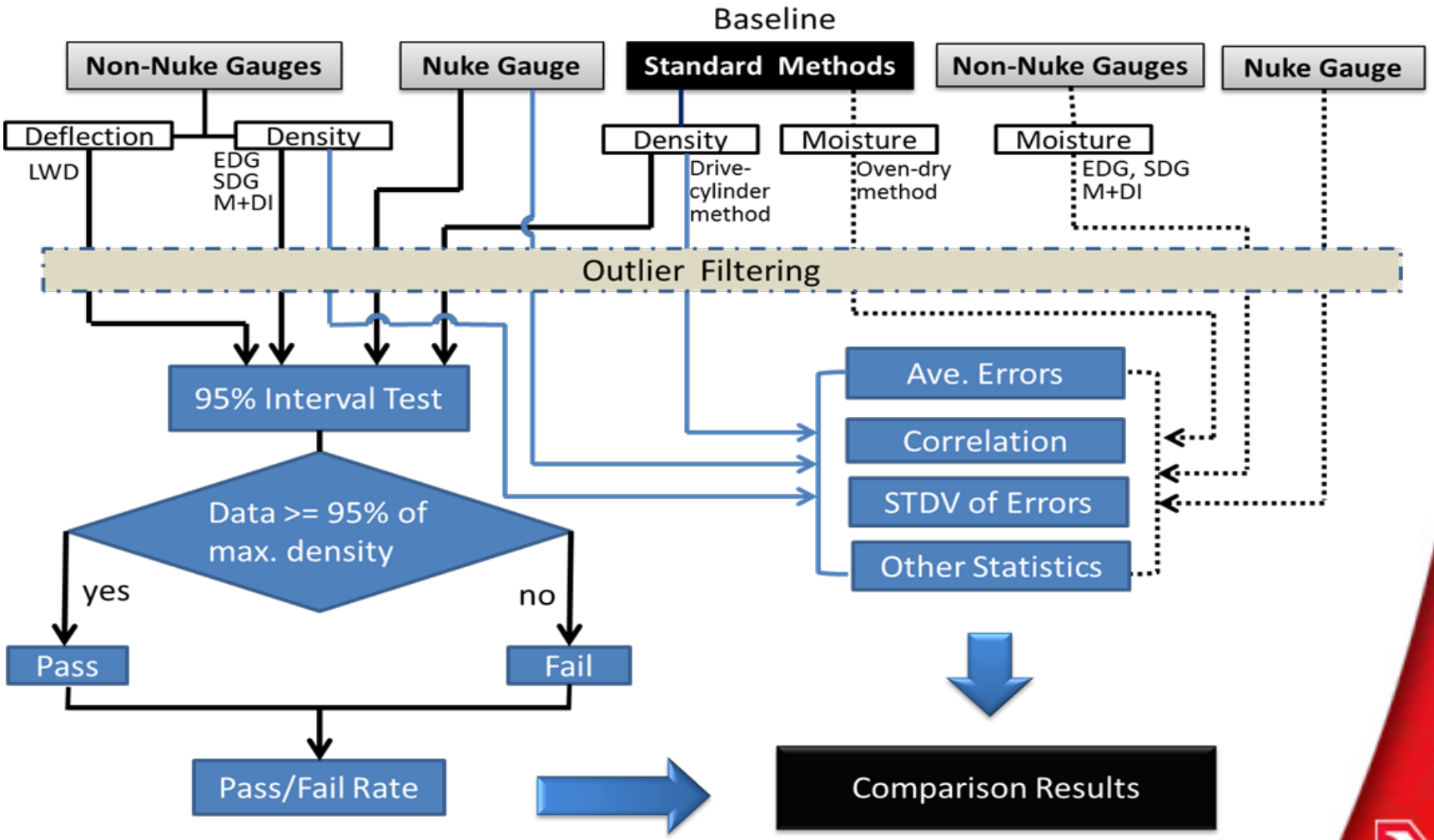
TransTech's PQI 380

TransTech's SDG 200

Framework of Evaluating HMA Gauges



Framework of Evaluating Soil Gauges



Conclusions

- Overall the nuclear gauge shows higher accuracy and correlation than non-nuclear HMA and soil gauges
- Methodologies to improve PQI's performance were developed and presented
- When cores and PQI had higher density (%), statistically PQI had higher accuracy than the nuclear gauge
- The trend line error modeling method showed the accuracy improvement when more cores were used for calibration.
- LWD shows promising test results (further discussed in next section)
- Great cost savings can be expected when non-nuclear method is adopted.